# Grain-grading in Canada by Electronics

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## 1. The Truth.

A well-monitored Affidavit system, in association with storage and electronic grading on the farm, can provide efficient grain-handing in western Canada into the 21st. century.

The system of marketing grains and seeds will change irrevocably during the next 10 (or even 5) years. And the system of grading and handling these commodities will have to anticipate this and be ready. **The research necessary to develop a system takes much less time than the implementation.**

Grain marketing is becoming more orientated toward purchase on specifications, and even by variety, rather than on grade. Add to this the increasing proclivity of marketing agencies to seek and service "Niche" markets. The complexities of these changes in marketing strategy, combined with the already progressing changes in elevator systems and grain transportation, will make it extremely difficult for the present system of visual grading to accommodate the demands of future grain marketing. Cereal processors need to know what the grain will do, and what types of grain can meet the requirements of their clients, rather than what it looks like. Indications are that the functional and analytical aspects of grain will become progressively more important in marketing than its appearance.

*The capability of kernel visual distinguishability (KVD) to differentiate among the six classes of wheat currently grown on the Prairies is already under stress. An increase in the number of wheat types could simply not be accommodated. On the other hand the number of niche markets is likely to increase.*

**Electronic grading is an inevitable development.** The research will take up to a further two years from now, but full implementation is likely to take a further five years, during which areas of improvement will be identified, and improvements will be made.

Another truth. Preservation of the identity of varieties, grades and classes of wheat by storage under an Identity-Preserved (IP) system has been suggested. This will not be practicable with the modern primary elevator system, with fewer, but larger bins. But it would be attainable through on-farm storage.

Four years ago the western Canadian grain-handling industry was issued the mandate to double grain-handling throughput by the year 2005. **This will be impossible without some form of Electronic system for grading and testing the grain.**

**2. The Philosophy.**

Why grade grains at all? The answer is Value and Price.

Why grade grains visually? The basis of this is that when grading became necessary (about 90 years ago in Canada) grains that looked best were assumed to be worth more than others. The visual system was developed and adopted because there wasn't any other way at the time.

Why grade grains electronically? There IS another way now! An electronic grade based on functionality means that grains with best functionality ARE worth more than others.

The Farmers and the Grain Elevator companies of western Canada - arguably the Mecca of grain-handling technology - have been well-served ( if not even "spoon-fed") since 1912, when the CGC (Canadian Grain Commission - then the Board of Grain Commissioners for Canada) was established. Canada's system for grading grains and seeds of all types has justifiably earned the respect and (possibly grudging) envy of the Grain world, in our ability to provide millions of tonnes of grains and seeds of consistent end-use quality. This has continued from year to year, despite the vagaries of weather during growing season, and harvest-time experienced in Canada (and in every exporting country).

The applied research necessary to implement systems for grading, evaluation of new plant-breeders' lines (variety development) and segregation by protein content has been carried out by government scientists and their support staff (let's never forget them). All of the costs, and the onerous responsibilities have been borne by the Federal government, through the medium of the CGC.

But the times - they are a-changing! And thence - the **need**. The need for more even more research to accommodate the new era of grain marketing - and the need for the beneficiaries (the farmers and elevator companies) to assist with the financing. Without their support the research can simply not be achieved within the time-frame (2005).

In other countries, such as Australia, which is looming large to make serious inroads to Canada's markets for canola and durum wheat, farmers welcome research, and contribute 1 % of the value of the crop toward the research which they know will benefit them in the long run.

**3. The Need.**

Foremost is the need to accept that grain marketing **will** inevitably change, and that grain-handling methods will need to change to address this.

The need to reduce costs of grain-handling, while improving the efficiency, has been addressed by western Canadian Grain Elevator companies by closing small elevators and establishing larger ones (Figure 1), with the capability of loading unit trains, each of which consist of up to 100 rail-cars of 100 tonnes capacity (wheat equivalent). Some of the new-era Primary elevators also have cleaning facilities, but all of them have bigger, but fewer cells (bins) than the older, more picturesque but less efficient elevators.

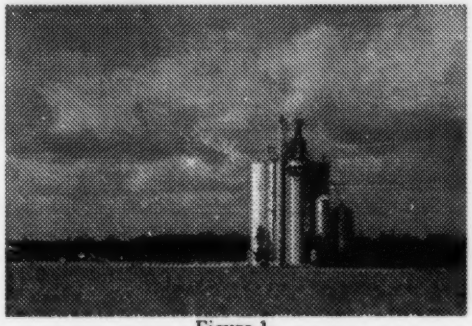

Figure 1.
A modern Primary elevator in western Canada.

This progression has only addressed part of the need, and has raised two new issues, of equal importance.

*A. Reduction in flexibility in storage.* Flexibility in storage has been reduced at individual elevators. In order to segregate all grades and protein sub-levels of wheat in western Canada an elevator would require at least 20 cells. This allows for only 2 protein sub-levels each, for grades 1 and 2 CWRS wheat, and does not cater for receipt of any other grains, oilseeds or pulses. Neither does it take into account the fact that the new larger elevators draw grain from a wider area around themselves than did the old ones, which means an increased potential for greater diversity of crops to be grown in the area served by the elevator. Also, in a

given season, while a wide range of crops and grades will have to be processed, weather conditions will cause one or more grades to dominate, and more than one cell will have to be assigned to the dominant grades.

This will become even more critical with the need to segregate and market **G**enetically **M**odified **O**rganisms (GMOs), or Transgenic varieties separate from "Normal" varieties. Most of the new elevators do not have this flexibility in cell-space, and are stand-alone elevators, whereas the older generation elevators were often grouped two or more (up to seven in some locations) at a receiving point. This allowed greater versatility, in that more cells were available to handle small volume crops/grades.

But farms have both the flexibility and the cell-space. While in a given region of - say - 100 square kilometres (or miles) a wide diversity of crops and varieties may be grown, most individual farms usually grow only up to 2 or 3 crops, so they do not need the flexibility required by an elevator. Moreover, while elevator storage space has shrunk to about 6 million tonnes, on-farm storage space has been estimated at 50 - 60 million tonnes, enough to store the entire crop in the normal season (Figure 2).

Figure 2.
A grain farm-yard in western Canada.

The need to segregate and preserve the integrity of GMOs, and individual varieties for "Niche" markets, as well as the larger volumes of the present statutory classes of wheat and other commodities will stretch well beyond the capabilities of the Primary Elevator network.

*The need will become increasingly important to identify grains and seeds by class and grade at the farm, so that the grains required by the elevator can be brought forward. This can best be achieved by an affidavit system, and electronic grading.*

**B**. Reduction in the degree of in-transit blending. Local growing conditions can exert a significant impact on grain quality (as defined by composition and functionality). Local preferences for varieties also influence the quality of grains. Table 1 illustrates differences in some composition and physico-chemical characteristics of CWRS wheat grown in 10 Prairie regions during the past three years. This pattern of variability in quality (and thence value) may be expected to be much greater with more diversity in growing conditions.

Table 1.
Influence of growing location and season on some quality parameters of CWRS wheat.

Under the old system a train may have had to travel a considerable distance to accumulate its complement of 90 cars. This meant that the grain was drawn from a much larger area than under the new system. The degree of blending which occurred during normal train assembly served to protect against excessive variability in quality within a grade.

Under the new system, whereby a single elevator can load the whole train, grain will be grown in an area relatively close to the elevator, so that variability in quality *within a grade and protein level* is likely to become a significant factor in supplying wheat (and other grains) of consistent quality.

The effect of growing location on wheat quality has not been thoroughly researched across the Prairie region. The system for registration of new varieties calls for three years of testing by growing potential varieties in several growing locations in western Canada. These are tested for quality at the Grain Research Laboratory, at the Agriculture and Agri -Foods Canada Cereal Research Centre, and at the University of Manitoba, Plant Science Department, all of which are located in Winnipeg. Due mainly to time restraints, the testing of individual lines is carried out on composite samples, rather than on the full series of lines from all growing locations. Each year protein content varies by up to over 5 % among locations. This must inevitably exert an influence upon the overall functionality of the wheat.

Quality tests, such as the Farinograph and Alveograph are prohibitively time-consuming, and the influence of growing conditions (location and season) on the variability of individual lines has never been thoroughly

evaluated for these parameters. In the light of the modern tendency, whereby grain will become drawn from smaller areas to a greater extent, stability of new genetic material to local growing conditions must become a factor in recommendation for registration. Lines which show excessive reactivity should be discarded.

**4. The Answer.**

The answer is a strictly-monitored Affidavit system, from farm through final shipment - a system monitored by the Canadian Grain Commission, still the official regulatory agency of the western Canadian Grain industry.

*Segregation of grains by grain-type, grade and protein or oil levels on the farm, accompanied by a strongly-monitored affidavit system would answer both 3A and 3B.*

What is the ideal situation? Views on this may differ, but the following scenario is attractive. With modern technology it is even practicable!

Picture a Prairie scene with all of the elevators equipped with Personal Computers (PCs). Most of them already have them. Picture also a series of farms, also with PCs - many of them already have them. Picture a network system which linked farm and elevator within the elevator region, or even Prairie-wide, whereby all farms declared what grain they held by class, variety and volume. The final brush-stroke in the tableau would be the ability of the farmer to estimate the grade and composition (in terms of protein and oil contents), as well as the tonnage.

This would enable elevator managers to bring forward the correct grades and grains required to compose the unit trains. Combined with a well-regulated affidavit system, this would also address the question of how to handle GMOs.

GMOs will be varieties that possess the full quality attributes of a grain type, such as CWRS wheat, barley or canola, but will likely not be allowed into statutory western Canadian classes. But the marketer and the elevator manager would be able to assemble and market a train-load of GMO grain of the quality parameters specified by purchasers. Local farmers would be able to ship all of their holdings of these varieties. The affidavit system would be monitored and protected by a spot-checking system, operated by the Canadian Grain Commission (CGC). Severe penalties would have to be imposed for farmers or elevator managers that tried to beat the system by blending off GMO grain with statutory grains.

The monitoring of the spot-check samples would call for a very accurate method for the detection of GMOs. It need not be a rapid test, since it would not have to be carried out at the elevator. The accuracy, rather than the speed, would be important.

A rapid test for variety ID carried out at the elevator would be of limited practical value. If the elevator manager was able to identify a GMO variety at the time of delivery, the GMO grain would have to be rejected, or stored in the limited storage space until it could be disposed of. This would squander a valuable cell from the elevator to store the small amount of grain, and would encourage the manager to attempt to blend it off (in the face of a possible spot-check, and heavy penalty). The alternative would be to send the GMO grain back to the farm, which would please neither the elevator nor the farmer.

An affidavit system served by a computer network, such as the system outlined above, would provide *instant* variety ID, and would serve all purposes. The growing of GMOs would likely require some restriction. But the ability to grow high-yielding transgenic crops as a proportion of their production, marketed by an alternative system, would potentially provide a badly-needed additional source of income for western Canadian farmers.

**5. The Method.**

a) The Technology
b) The Software
c) The Samples
d) The Grades
e) The Costs

*a) The Technology.* Near-infrared (NIR) spectroscopy offers the potential to achieve the system proposed under section 3 above. Recent advances in the technology have enabled its extension to the prediction of functionality, as well as composition, in wheat[1]. These advances have included both changes in instrument design and in presentation of the sample to the instrument. Digital Imaging is also reaching a stage of maturity. A combination of NIR with digital imaging would provide all of the elements necessary to electronic grading

*b) The Software.* Improvements in NIR software have greatly improved the qualitative aspects of NIR applications. This improvement owes its origin to the Pharmaceutical industry, where NIR is employed in identification of the contents of tablets and other forms of prescribed drugs. Innovations such as Neural Network software have enabled NIR technology to become a powerful method for the identification of a very wide diversity of commodities and materials, including grains.

*c) The Samples.* The successful application of any analytical technique lie at the mercy of the integrity of the sample.

On-farm sampling will involve providing farmers with simple, practicable and efficient methods for sampling storage bins, and for subsequent safe storage of the samples. Sampling of fields presents less of a difficulty, since automatic samplers have already been designed to fit onto combine harvesters. These will enable farmers to assemble samples of their grain during harvesting. With careful preservation of the sample identity, the same samples could be used to represent storage bins.

*d) The Grades.* The present grading system relies heavily on two factors - on efficient visual grading by grain inspectors, and on the western Canadian system for registration of new varieties, (the PRRCG system) which has been described earlier in this series of electronic articles. The releationship of visual grades to actual functionality has been determined by research at the CGC's Grain Research Laboratory.

A new concept of grading is proposed for identification of grain at the farm level. This will incorporate the texture and functionality of the grain, as well as its composition. Visual factors such as damage caused by frost, sprouting and *Fusarium* head blight will be incorporated in the development of the calibration, and will continue to be involved in assigning the grades.

Table 2.
Grading factors, Present and Proposed

The most important factor determining the value of grain is its functionality - will the grain prove suitable for the manufacture of the products for which it is to be purchased. Under the present system of visual grading the most important parameters affecting the "brightness", or appearance of the grain are fairly loosely defined. For example Grade 1CWRS and Grade 1CWAD wheat have to be "Reasonably well-matured", and "Reasonably free from damaged kernels". Minor, but important grading factors, such as Black-point or *Fusarium* damage are assessed less subjectively on a percentage basis, where necessary by hand separation. Due to differences in things such as lighting, and the human element, agreement among grain inspectors is not always easy to achieve.

Under an electronic grading system, the most important factors, such as texture and physico-chemical properties would be determined electronically. Factors such as *Fusarium* damage in wheat, or chlorophyll content in canola seed can be identified by NIR spectroscopy. They will be incorporated into in the calibrations, and grains will be degraded as a result of these "percentage" factors in the same way as by the visual system. Modern NIR instruments can be expected to agree among each other to a high degree, since all instruments will receive the same calibrations.

*e) The Costs.* Instruments for NIR and digital imaging analysis are expensive at present. But recent innovations to NIR instrumentation have realized a low cost instrument for application on farms. This, combined with the potential of very high volume sales, should make NIR analysis available to farmers. The instruments are designed to operate on combine harvesters, as well as in a free-standing format. Farmers will be able to obtain the mean protein content of their wheat as it is being harvested. This information is also being processed to assist in efficient application of fertilizers, in connection with the concept of Precision Agriculture.

**6. The Strategy**

a) The Instruments
b) The Evaluation
c) The Software
d) The Grades and grading factors
e) The Samples

Development of an electronic system for grading and testing involves five steps, all of which equally important.

a) The first is the evaluation of NIR instruments for their suitability for determination of the degree to which they are capable of distinguishing differences in grain caused by agencies such as infestation by fungi or insects, frost, sprouting, and others, and translating them into a format whereby they can be used to assign a grade. Flexibility in wavelength range, and instrument durability will likely be among the most important attributes of the selected NIR instrument.

b) Next is the determination of the degree to which NIR technology can be used to predict reliably grading factors such as kernel texture, sprouting, fungal or insect damage, as well as functionality, all in whole kernels, for incorporation into the final working algorithms.

c) Software suitable to enable the instrument to achieve the requirements described in (a) above must be evaluated. Apart from conventional multiple linear, and principal component regression, artificial neural networks and discriminant analysis will be investigated. The development of a reliable system will involve writing new, or expanding existing software, with the ability to recognize the significant grading parameters such as kernel texture, incidence of sprouting or frost damage and others,, assign their relative degree of importance, and incorporate them into a functional grade.

d) The new grades will be determined on the basis of grain texture (in the case of wheat and barley), functionality, in terms of parameters such as physico-chemical characteristics, malt extract, etc. and other factors, including those in table 2 which form part of the present visual grading system. Under the proposed system a sample will be graded electronically on the basis of its potential value, and on the presence of factors likely to reduce the potential value.

e) Assembly of a comprehensive data-base which will include many examples of grains carrying differences caused by these factors is the fourth prerequisite. It is estimated that 5,000 - 6,000 samples will constitute the final data base, which will be augmented each year with new crop grain. The CGC annually processes between 200,000 and 300,000 rail-carloads of grain of all types, in connection with the export trade. In addition, samples involved in assembling cargoes, in the annual preparation of grade standards, and surveys of the quality of the new season's crops adds about a further 50,000 samples, so that there is an abundance of variance available. Samples of Plant-breeders' lines will supply even more variance in quality factors. Professional grain inspectors will determine the degree of the various visual grade factors displayed by individual samples.

**7. The Progress.**

Work on determination of the degree to which NIR can predict factors such as kernel texture, sprouting (as indicated by Falling Number), wheat functionality and damage caused by *Fusarium* began several years ago. Table 3 summarizes the results to date. All of the work has been carried out on whole kernels or seeds.

Table 3.
Progress in development of an electronic grading system

These data are already satisfactory for inclusion in development of grading algorithms. The reproducibility is also adequate for all parameters.

**8. The Implementation.**

*a) The Crop.* The choice would be between a crop for which the work had reached an advanced stage of completion, or a small volume crop, such as western Canadian Soft White Spring wheat, where the economic impact would likely cause less concern. Based on the data of Table 3, the most practicable crop for the introduction of an electronic grading system appears to be canola seed. The grade would be based mainly on chlorophyll content, and the crop could be segregated on the basis of oil content. Both chlorophyll and oil contents can be predicted with reliable accuracy and reproducibility by NIR spectroscopy.

The economics of an electronic grading and segregation of canola seed would be attractive. The average oil content of canola seed in western Canada is about 45 %. Premiums for oil content could be paid on a basis of 2 % of the basic value of the crop for each 1 % increment in oil content, starting at an oil content of - say - 42 %. Canola oil content covers a range of from about 36 to 53 % every year. On the basis described, canola with an oil content of 53 % would carry a premium of nearly $60 per tonne. Money could also be made on the seed with an oil content of 42 % or a little lower, since it could be purchased at the basic price, and blended with high oil canola to secure a premium. Furthermore, with a "normal" differential of about $12-13 per tonne between grades 1 and 2 canola seed, 2 CW canola at 50 % oil would be worth several dollars per tonne more than 1 CW at 45 % oil. The research on rapid testing of whole canola seed for chlorophyll and oil contents has already been completed, and the development of an electronic system for grading and segregation of canola seed could be initiated immediately.

Under the present system this potential source of revenue is not fully exploited.

*b) The Place.* Electronic grading would best be introduced at the farm level - its forté will be to enable the elevator/farmer system to bring grain of the right class, composition and functionality forward. The rôle of the elevator companies would be to get the right grains and seeds in place for shipment at terminals, or directly to both domestic and non-Canadian clients. The responsibilities of the CGC would include monitoring all outward shipments, as at present, and also to monitor the Affidavit system, and carry out the necessary testing to verify variety ID. Other duties would include provision of training in grading, and provision of standard samples.

The electronic system would be introduced to streamline movement of grain into position for marketing, both domestically and for export. At the outset, outward shipments of grains and seeds by ship or rail would continue to be monitored by CGC grain inspectors, using the visual methods, as at present, out of respect for clients who have become familiar and comfortable with the Canadian system. As the system becomes refined, and clients become accustomed to its use, it is anticipated that electronic grading will become the preferred method, both in Canada and elsewhere.

**9. The Benefits.**

The Proposed system (electronic grading, on-farm storage and grading, in association with a CGC-monitored affidavit system) will:

1. Enable instant variety identification, without the need for a rapid "Black Box" type of instrument
2. Streamline grain-handling and transportation, by identifying grains by grade and composition at the farm
3. Improve the efficiency of grain-storage and handling throughout the Primary Elevator system,
4. Answer the question of identity preservation of transgenic varieties and individual varieties for "Niche" markets (including organically-grown grains)
5. Answer the question of variability in results for Near-infrared protein content (and other constituents), since instruments will operate using the same calibrations
6. Introduce a system whereby elevator companies and farmers will legitimately be enabled to market commodities such as transgenic wheat and barley varieties of appropriate quality.

**Reference.**

[1]. Prediction of wheat bread-making functionality in whole kernels using Near-infrared spectroscopy. 1998. Pawlinsky, T, and Williams, P.C. *J. Near-infrared Spectr.* 6: 121-127.

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